C. Preliminary Results of the 1962 Radar Astronomy Study of Venus

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Continuous wave spectra were obtained by transmitting a 13-kw, 2388-Mc signal toward Venus and computing the spectrum of the received echo. An 85-ft parabolic antenna at Goldstone was used alternately for transmission and reception by switching between the two modes in accordance with the signal's round-trip time. An ephemeris-controlled receiver was used to remove the echo's doppler shift due to the relative velocity between Earth and Venus. The transmitted signal was less than one cycle wide, and any broadening of the echo is due to the relative velocity of different parts of the planet. These differences may be attributed to the apparent rotation of Venus; however, other possibilities exist. For example, if Venus were rotating synchronously it would probably librate as well, and this could complicate the interpretation of Venus' measured angular velocity. Also, it is possible that parts of Venus' surface itself may change with time due to weather or volcanism.

Fig. 3 shows the spectrum obtained on November 10, 1962. It was computed on the IBM 7094 computer from approximately an hour of recorded data. The ordinate is relative signal power (per unit bandwidth), and the abscissa is frequency. The plot can be equally interpreted as signal power vs radial velocity relative to the center of the planet. The peak corresponds to zero radial velocity. The spectrum has a resolution of 1 cps or a radial velocity resolution of about 6.3 cm/sec! The sketch above the spectrum shows the relation between the spectrum and the regions on Venus from which the signal may be reflected, based on the important assumptions that the axis of rotation is perpendicular to its orbit and that energy was being received almost to the limb.

Of particular interest is the detail on the lower left side of the spectrum. At least a suggestion of a similar detail was found on all but two of the spectra obtained in the month preceding conjunction. Fig. 4 shows the position of various details relative to the peak of the spectrum. The ordinate is the date of the observation and the abscissa is the frequency difference between the peak and detail in cps. The width of the boxes corresponds to the approximate width of the detail. The filled boxes are considered good identifications, while the unfilled and dotted ones are fair and poor, respectively.

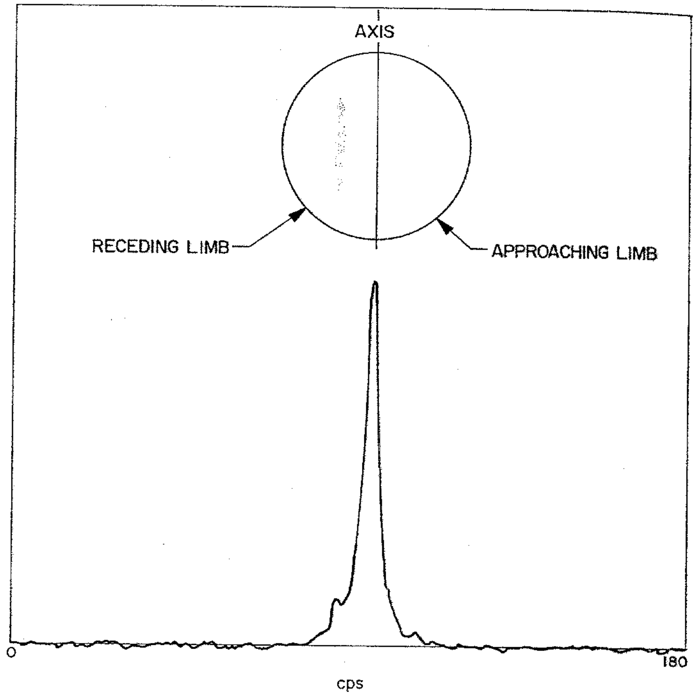

Fig. 3. CW radar spectrum of Venus, November 10, 1962

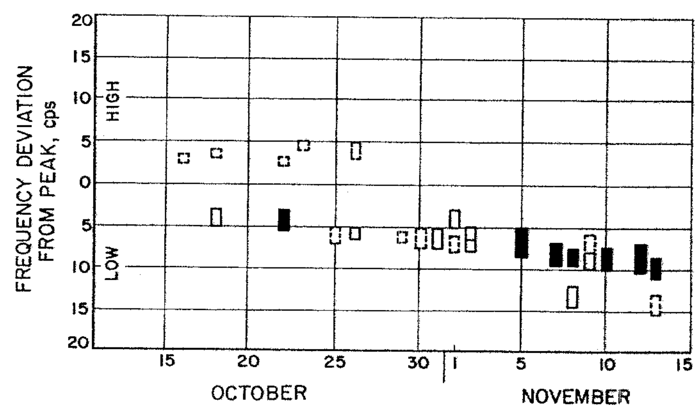

Fig. 4. Position of detail on spectrum relative to the central peak

There is an obvious continuity in the position of the best identified details which strongly suggests that they represent one and the same spectral detail which has moved slowly across one side of the spectrum. If this detail is the result of an actual topographic structure on the surface of Venus, then the rate at which it moves may be used to estimate the planet's rotation period. To obtain the rotation rate the position of the detail on Venus must be known. The longitude of the detail, relative to the center of the planet's disk, may be estimated by measuring its position relative to the maximum observable half width of the spectrum's base. This assumes that the spectrum extends to the limb of the planet. If this is not the case, the longitude of the detail will be over estimated, which will result in over estimating the rotation rate.

Using a composite spectrum constructed by averaging the spectra of November 7, 8, 9, and 10, the estimated longitude obtained was 23 ± 3 deg. The given set of spectra was chosen because it fell in the middle of the period of the best position estimates of the detail. The latitude of the detail cannot be found from the current data, and it will be assumed equal to 23 deg as well. Fortunately, the derived rotation rate varies as the square root of the secant of the latitude and longitude; hence, the rate is insensitive to the detail's position if it is within 45 deg of the center of the disk.

The estimated rate of which the detail was moving across the spectrum for the week prior to conjunction is 0.28 (+0.30, −0.10) cycles/day. This corresponds to an apparent angular velocity of $2.0\,(+0.87, -0.41) \times 10^{-7}$ rad/sec. Synchronous rotation would be approximately 4.5×10^{-7} rad/sec. The apparent angular velocity of Venus is the projection on to a plane perpendicular to the line of sight of the sum of two components: (1) a component due to the rotation of Venus on its own axis and (2) a component due to an apparent rotation caused by Venus passing the Earth in space. If it is assumed that the axis of Venus is perpendicular to its orbit, then the angular velocity found corresponds to a sidereal rotation period of over 1000 days forward or 230 (+40, −50) day retrograde. The 1000 days forward can be rejected because it leads to spectral bandwidths of about 20 cps for periods of several weeks before and after conjunction, and such a narrow bandwidth was not observed.

The effect of tipping the axis in different directions is under study; however, a tip of nearly 70 deg toward the Earth would be required to give the same apparent angular velocity if Venus were rotating synchronously (227 days forward). The axis would have to be tipped even more for faster rotation rates.

Combining a range-gate with spectral analysis enables one to measure directly the component of Venus rotation which is perpendicular to the line of sight. This is so because the range-gate (a device which accepts echoes from a specified distance, but rejects closer and farther echoes) selects a known portion of the surface of Venus; and the spectrometer, utilizing the doppler effect, measures the line of sight velocity of that portion.

The range-gate operates by the principle of modulating the transmitter with a wide-band waveform, and modulating the received signal by the waveform's inverse (delayed by the time of flight). Echoes from the proper distance thus pass through the system unaltered, but they remain wide-band from other distances and may then be removed by filtering.

The true period of Venus rotation is inferred by several measurements of the perpendicular component, spaced over an interval of several weeks. A rotation period of 250 days retrograde fits the data very well, under the assumption that the axis of rotation is perpendicular to the orbit.

Fig. 5 is a sample of the raw data. The reflection from the cap, or zone one, contains most of the power. It is quite a narrow band. The echo from the first annular ring, zone two, shows the characteristic double hump and

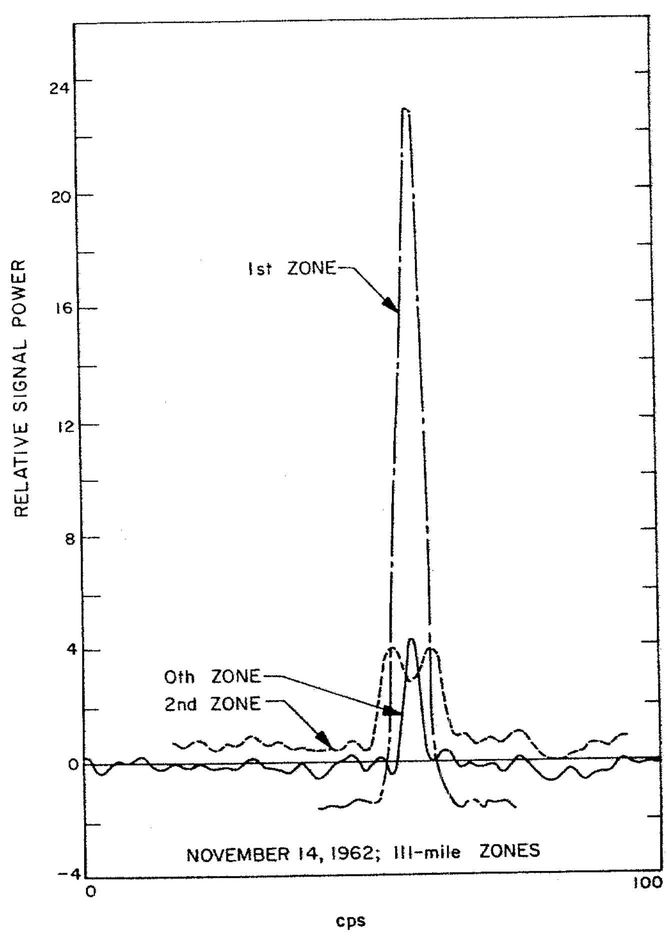

Fig. 5. Range-gated spectra

increased doppler broadening. It is the width of this curve that is used to infer the angular velocity. Zone zero is the area just ahead of the planet. Normally there would be no power from that zone. However, the range-gate has been misalined slightly to allow the position of the range-gates to be calibrated from the amount of power in zone zero. These spectrograms required 3 hr of integration time.

Fig. 6 shows how well the theoretical curve, calculated from the Earth and Venus ephemerides, fits the data. The ordinate is angular velocity, measured in cycles per second of doppler spreading (limb-to-limb).

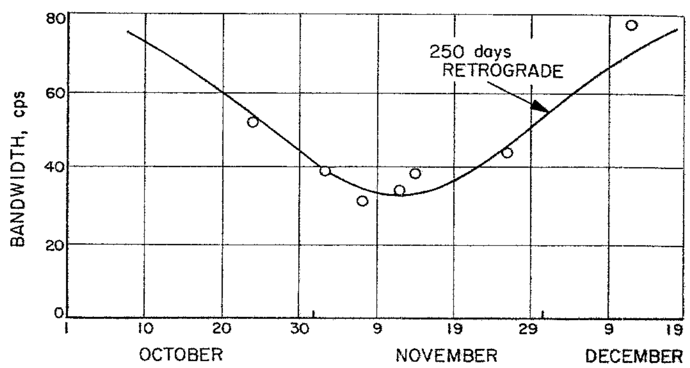

Fig. 6. The limb-to-limb doppler spreading derived from range-gated spectra

D. The Stellar Content of NGC 3379

H. Spinrad

1. *Introduction*, *H. Spinrad*

NGC 3379 is an EO galaxy of moderately high luminosity ($M_{pg} \simeq -20$). From analysis of line profiles in the NGC 3379 spectrum, two estimates of the mass-luminosity ratio have been recently published: $M/L_{pg} = 12$ (Ref. 15) and $M/L_{pg} = 24$ (Ref. 16). In view of the difficulties in determining the distance to NGC 3379, and since different absorption lines were used in the velocity dispersion calculation, the agreement between them seems satisfactory. For the purpose of comparison with a model we adopt a mean visual ratio of 15. This value is an order of magnitude higher than the value of M/L_v found for the solar vicinity by Perry, Roberts, and Stableford (Ref. 17). Such a marked difference in M/L alone leads us to suspect a basic difference in the stellar populations involved.

NGC 3379 was observed by Whitford and Sears in 1961 on their six-color photometric system. Spectra are also available for NGC 3379; the writer obtained an excellent low-dispersion spectrogram at the Crossley reflector in 1961, and Osterbrock (Ref. 18) obtained several spectrograms with the Hale reflector at 180 Å/mm several years ago. The Crossley spectrogram is well exposed from $\lambda\lambda$ 3900–6600. The spectrum shows Hα absorption, weak TiO at λ 6158, strong NaD lines, a strong MgI "b" blend at λ 5167 − 84, moderately strong CaI λ 4226 and the usual G-K spectrum in the blue and ultraviolet. The equivalent width of λ 4226 was measured on the Palomar spectrograms kindly loaned by Dr. Osterbrock, who has already published EW values for Hα and Hβ (Ref. 18). The D-line strength must be estimated from the Crossley spectrogram and one of the Palomar plates. The values of equivalent width may be in error up to an estimated 25%. With these data and the Whitford–Sears six-color photometry a crude stellar synthesis of the EO galaxy can be constructed. The resulting stellar content should satisfy the observed M/L_v of 15.

2. *A Crude Synthesis for NGC 3379*, *H. Spinrad*

The procedure of the synthesis is identical to the spectrophotometric analysis used by de Vaucouleurs and de Vaucouleurs (Ref. 19) and Spinrad (Ref. 20). A first approximation to the stellar population (using only four or five constituents for simplicity) is guessed from the spectral features and colors of NGC 3379. TiO is present in the red, implying some M stars; the Balmer lines are fairly strong, implying stars hotter than the Sun. The presence of a CN band in the ultraviolet suggests a contribution by K giants, while the strong D and Mg "b" blends must be due to late-type dwarfs (Ref. 20). We then arbitrarily select four "normal" stars, such as an F8 V, F5 V, KO III, and MO V, which *qualitatively* account for the observed spectral features. The synthesis attempts to blend them together in such a way as to satisfy the observed equivalent width values and the colors. In general, several iterations are necessary; the final check on the physical significance of the mathematical exercise is the comparison between the observed and derived M/L_v ratios.

In this case the stellar equivalent width values for D, λ4226, Hα, and Hβ were extracted from papers by Williams (Ref. 21), Stock (Ref. 22), Günther (Ref. 23), and Spinrad (Ref. 20). The stellar colors are due to Stebbins and Kron (Ref. 24). Table 2 lists the stellar data of interest.